

K. T. Winther
7 Walnut Street
Upton, MA 01568-1101
508-529-0093

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Amendment A

Cross reference to Related Application

The present patent "Bonding of Materials with Dissimilar Thermal Expansion Coefficients" is entitled to the benefit of Provisional patent Application number 60/273,070 filed on March 5, 2001. The original disclosure is attached.

Very respectfully,

K.T. Winther

Kaspar Tobias Winther

Title: Materials for bonding parts with dissimilar thermal expansion coefficients.

Inventor: Kaspar Tobias Winther, 400 Brunswick Drive, B10A12, Troy, NY 12180, citizen of Denmark.

Invention conceived: 2001 February 14.

First sketch of invention prepared: 2001 February 14.

First written description prepared: 2001 February 15.

People (other than inventor) who have knowledge of the invention:

Harry Stephanou

Beth Wales

Bob Reinick

Mark Pazder

Dan Popa

Problem addressed:

Permanent bonding between dissimilar materials is required in many products and components. In most cases the two materials will have different thermal expansion coefficients so when the temperature change fractures may form at or near the interface between the two materials. The fractures will naturally weaken the bond and eventually cause the parts to come apart. The temperature changes may reflect cooling from the processing temperature at which the parts were bonded to ambient or temperature cycles during the lifetime of the product / part.

Alternative solutions to the problem and their shortcomings:

There are basically two different approaches used today:

1. Use materials that match each other as closely as possible in terms of thermal expansion coefficients. Corning is for example offering a number of different specialty glasses that match a number of different materials in their thermal expansion coefficient. The problem with this approach is that these materials may otherwise have undesirable properties, e.g. maybe one component must be manufactured in silicon while another must be manufactured in metal, so Corning's glasses is of little help. Another issue is that the match in thermal expansion is often limited to a certain temperature range.
2. Use an intermediate layer that has sufficient compliance to take up the thermal mismatch. This layer could be an adhesive or either one or more layers of metals. The drawback of adhesives like epoxy is that they may decay over time and may not

withstand a number of environments. The drawback of the metal layers is that they themselves have different thermal expansion coefficients that ultimately can cause problems of their own.

Description of the invention:

Let us assume that we want to bond two materials, A and B, together with the thermal expansion coefficients α_A and α_B , respectively. The basic idea is to first form a sheet of glass or metal that gradually changes thermal expansion coefficient from α_A on one side to α_B on the other side and secondly bond the two materials, A and B, to this sheet. The fabrication of this sheet could be done in a number of ways; here are some examples:

- Two existing layers of "end-member" materials are polished, placed against each other and heated under pressure. The diffusion taking place will create a gradient in compositions and physical properties. Especially, for relative simple systems like two glasses with different Na to K ratios the changes in thermal expansion coefficients can be expected to be a monotonous (although not necessarily linear) function of composition. Similar sheets can be formed by alloying two different end member metals or alloys. After the diffusion, stress relief of the glass will most likely be required.
- Forming the glass or metal directly with a gradient, this could be done by simultaneous extrusion of different compositions, rolling of multiple layers or build up sheets of xerogel precursors with changing compositions followed by sintering. Subsequent heat treatment will further smoothen the gradients.

The bonding of the materials, A and B, to the sheet can take place with anodic bonding, diffusion bonding, adhesives or other methods. The thickness of the intermediary sheet will naturally have to depend on the difference in thermal expansion coefficients (between α_A and α_B), the elastic properties of the sheet and how uniform a gradient in thermal expansion coefficients can be achieved within the sheet.

Benefits over prior art:

The key benefit of this method is that the thermally induced strain is distributed across a layer of material rather than being concentrated at the interface. In this way the stress at any given point is reduced, and the material remains in the elastic region so cracks are avoided, thereby creating the basis for a long-term durable bond.

Problems that remain unresolved:

- The intermediate layer will, like Corning's specialty glasses, only match the thermal expansion coefficients of the neighboring materials over a certain temperature range. Of course if the two end-members are the two materials that need to be bonded together even this problem will go away.
- Additional thickness will be added to the structure being constructed.
- The compatibility of the intermediate layer will have to be verified.

None of these problems are, however, avoided in the currently used methods.